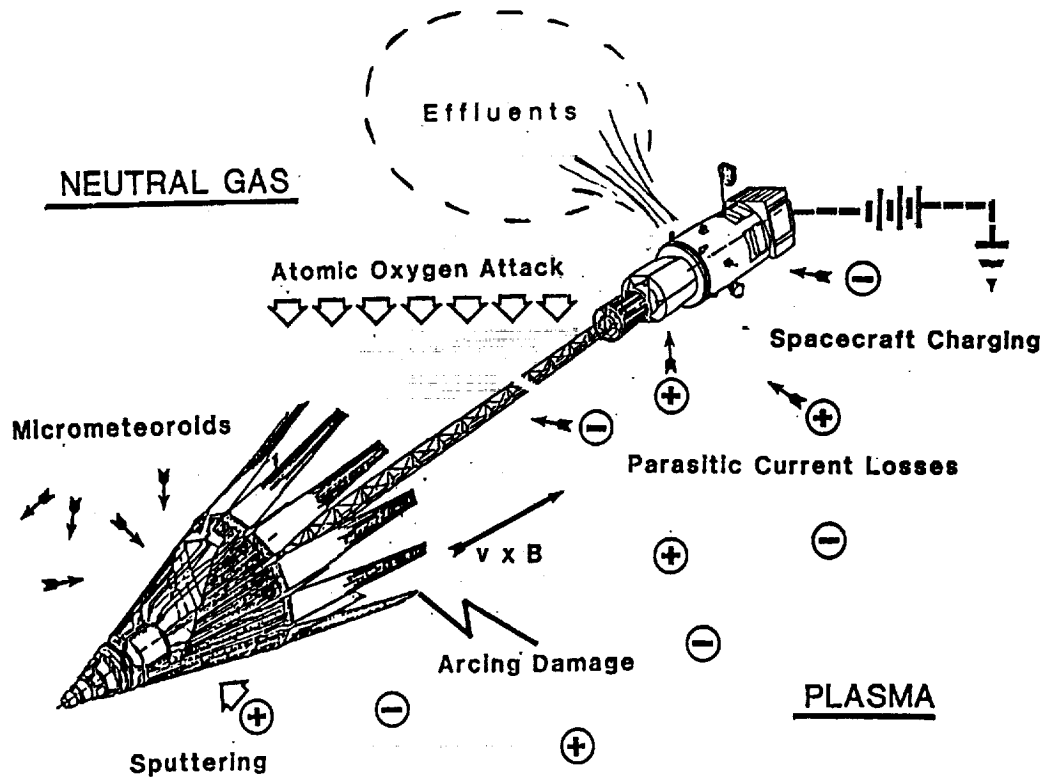


## SPACE ENVIRONMENTAL INTERACTIONS FOR THE SPACE EXPLORATION INITIATIVE

Dale C. Ferguson  
National Aeronautics and Space Administration  
Lewis Research Center  
Cleveland, Ohio 44135

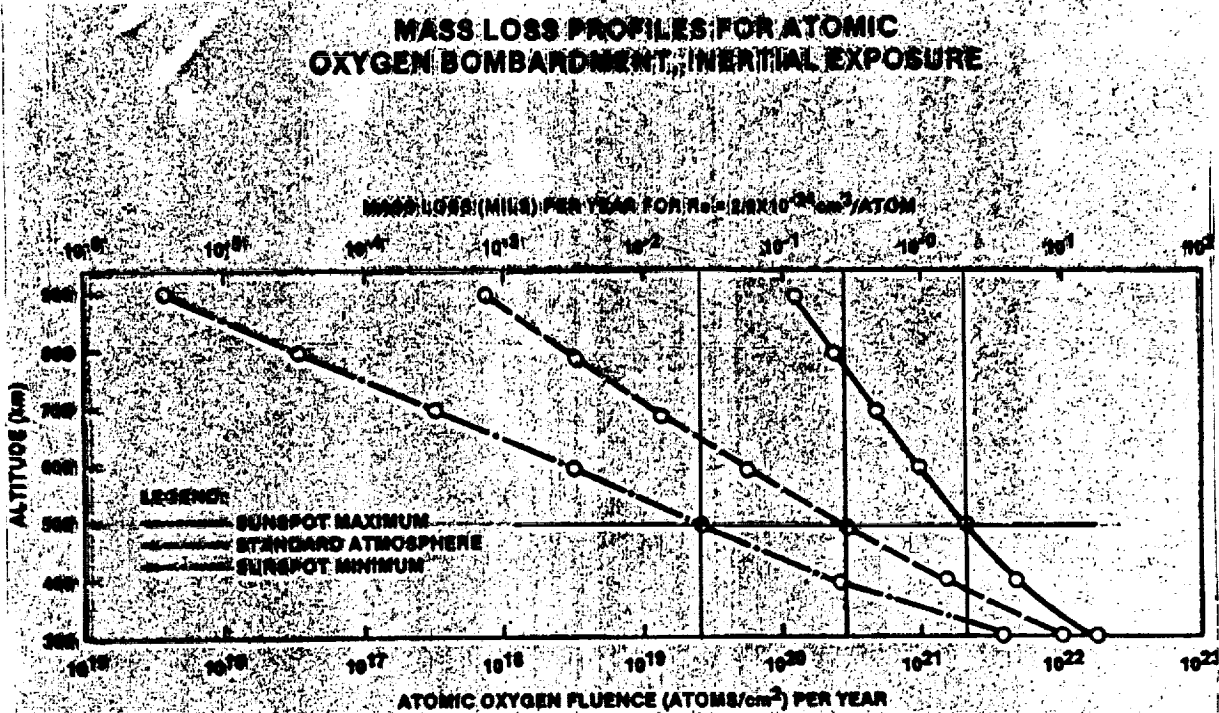
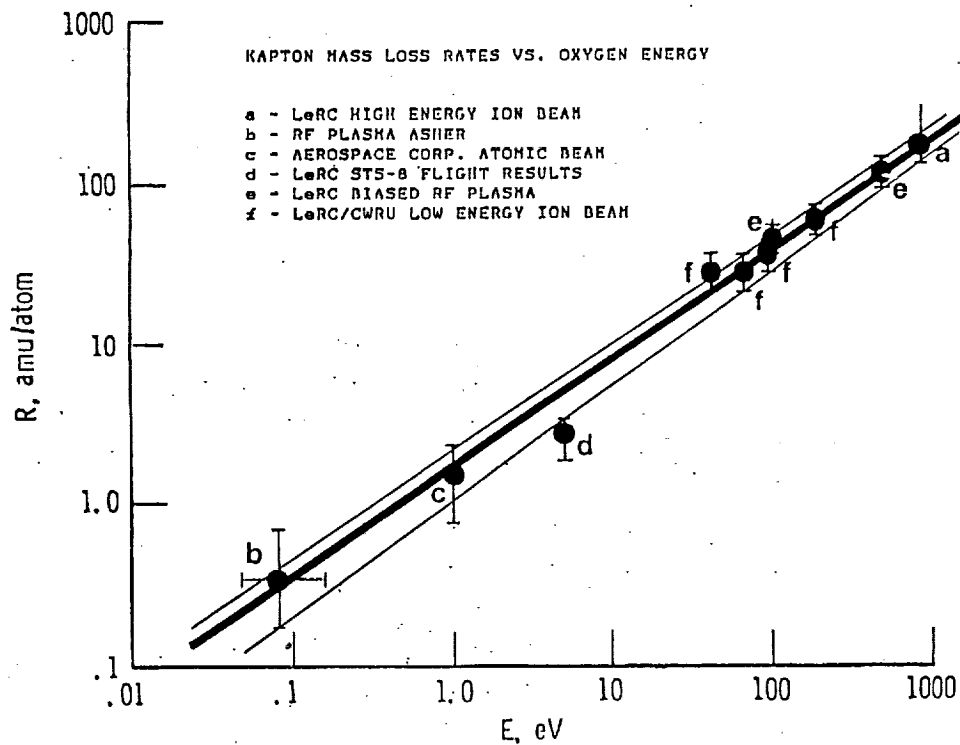
## SPACECRAFT ENVIRONMENTAL EFFECTS



## Space Environmental Interactions

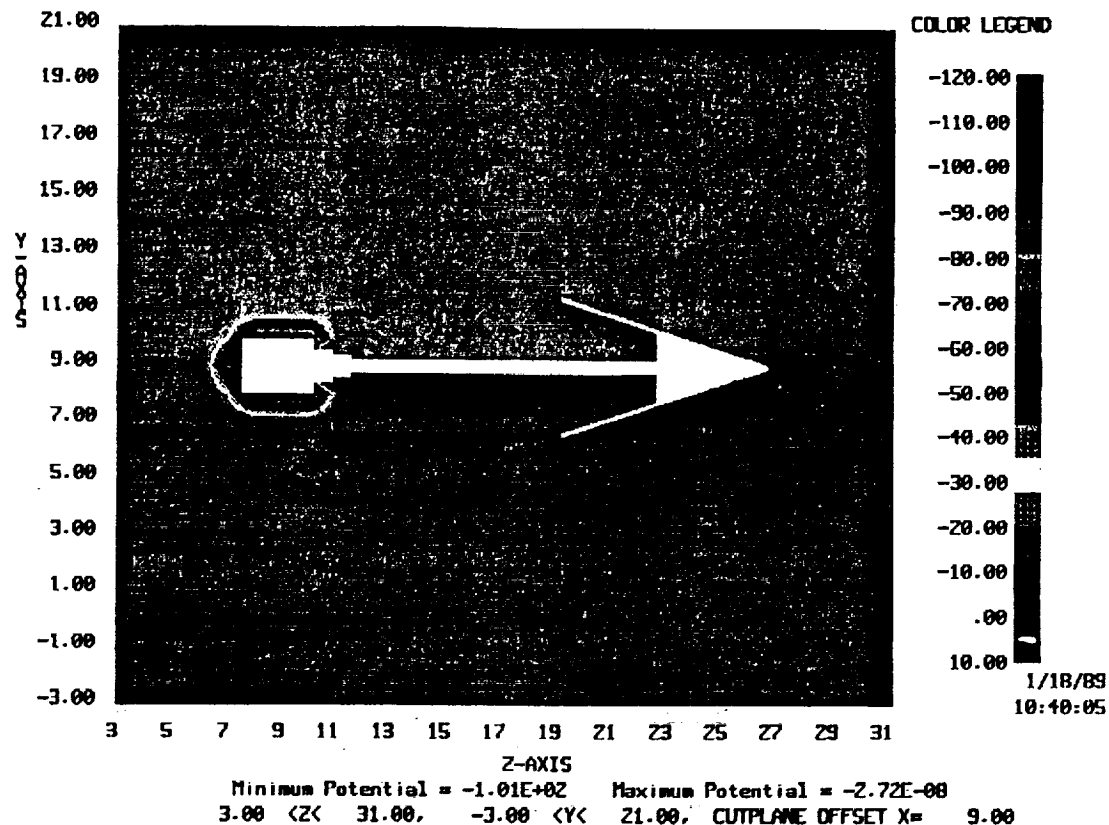
### Atomic Oxygen Attack

- **LOW PLANETARY ORBITS ONLY**
  - Material Specific
  - Preferentially in Ram
  - Low Mars Orbit Also Contains AO
  - For Some Materials, Synergy w/ UV
  - Ionized AO Also Reactive.
- **CHANGES MATERIAL SURFACE PROPERTIES**
  - Optical and Thermal Properties
  - Surface Conductivities
  - Strength of Exposed Fibers



Copyright © AIAA 1986 - Used with permission. Visentine, J.T. and Leger, L.J., A Consideration of Atomic Oxygen Interaction with the Space Station, J. Spacecraft and Rockets, 23, 5, 505-511, 1986.

Load Biased to 100V Neg. w.r.t. Body



## Space Environmental Interactions

### Arcing and Discharges

- GEOSYNCHRONOUS ENVIRONMENT
  - Differential Charging in Geo Substorms
  - Solar Flares in Interplanetary Space
- LOW PLANETARY ORBITAL ENVIRONMENTS
  - Arcing To or Thru Ionized Plasma
  - Dielectric Breakdown of Anodized Surfaces
  - Arcing at Conductor-Insulator Junctions
- PASCHEN BREAKDOWN - PLANETARY SURFACE
  - Martian Atm Pressure Ideal for Discharges
  - Lunar Camps Create Local Atmospheres

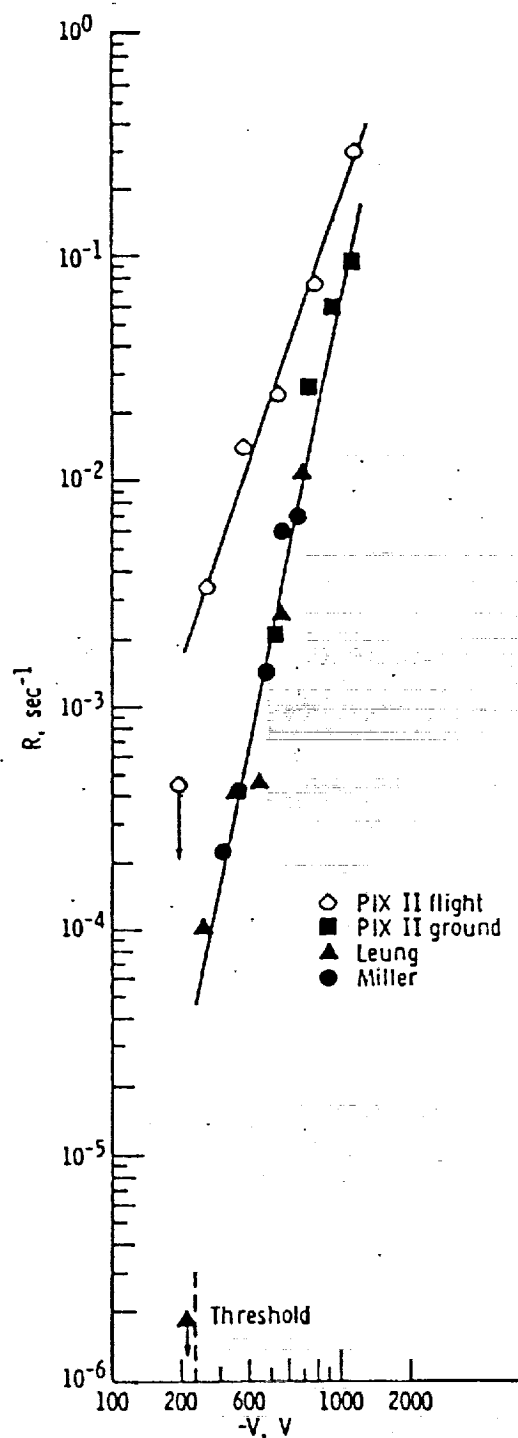


Figure 7. - Arc rate versus voltage for standard interconnect cells. Normalized to LEO ram conditions (see text).

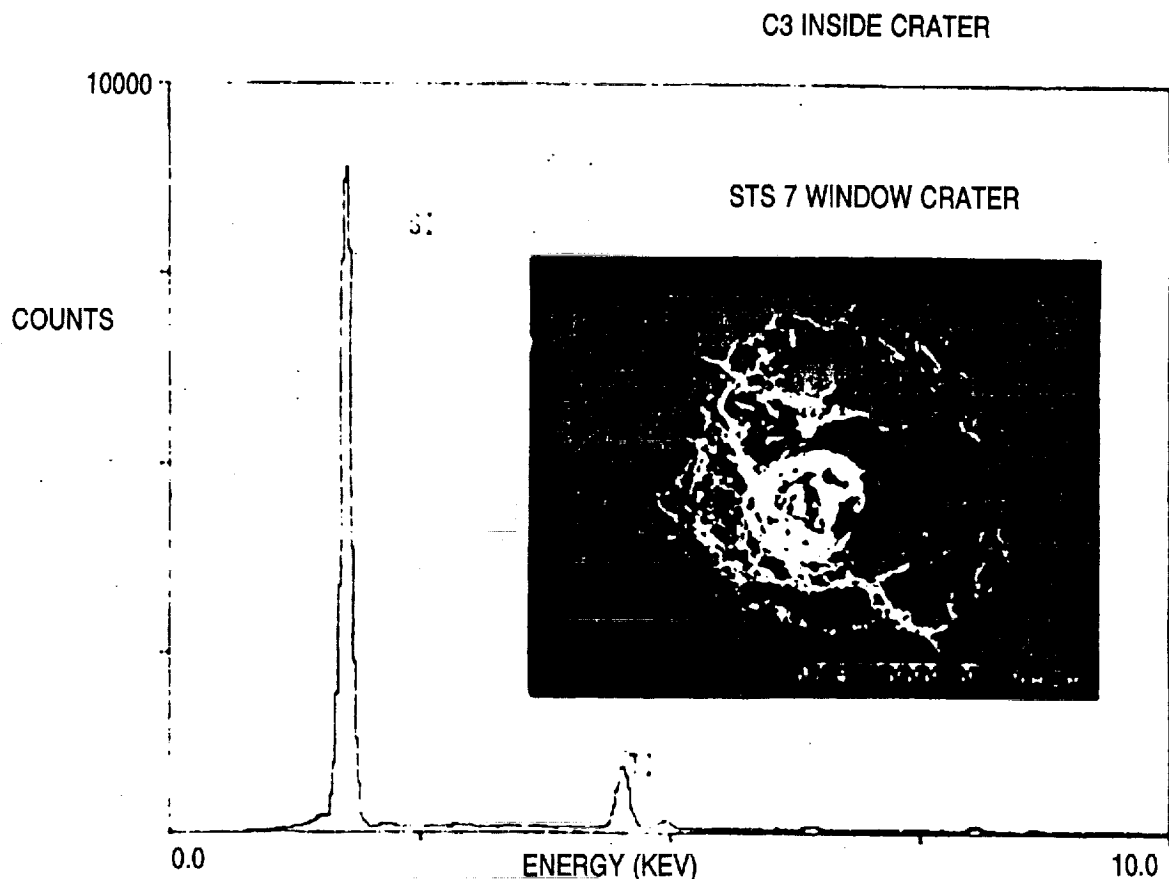
Copyright © AIAA 1986 - Used with permission. Ferguson, D.C., The voltage threshold for arcing for solar cells in LEO-flight and ground test results, AIAA paper 86-0362, 1986.

# Space Environmental Interactions

## Micrometeoroids and Debris

---

- **SURFACE DAMAGE**
  - Pinholes in Insulators
  - Change of Thermal Properties
  - Sites for Arcing, Sputtering
  - Possible Site of Kapton Pyrolysis
- **NEED FOR REDUNDANCY OR HEALING**
  - Fluid Lines and Heat Pipes
- **LOCAL PLASMA CREATED AT SITE**
  - May Produce Prompt Arcing
  - Arcs Enlarge Damaged Area
- **DEBRIS PROBLEM IN PLANETARY ORBITS**

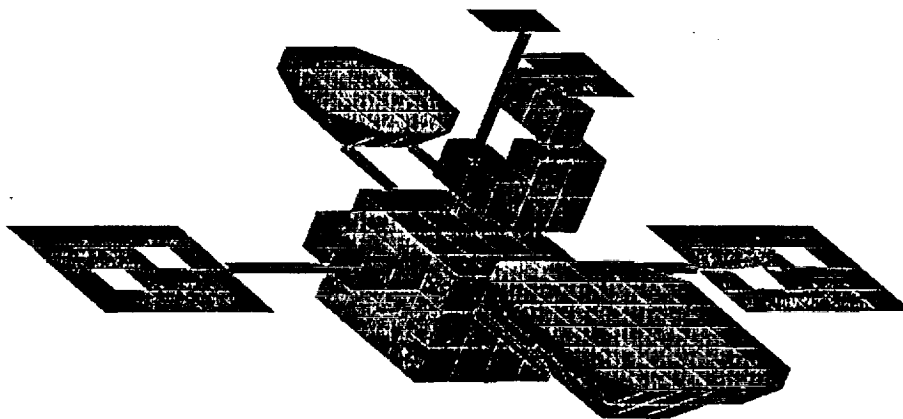


# Space Environmental Interactions

## State-of-the-Art Computer Tools

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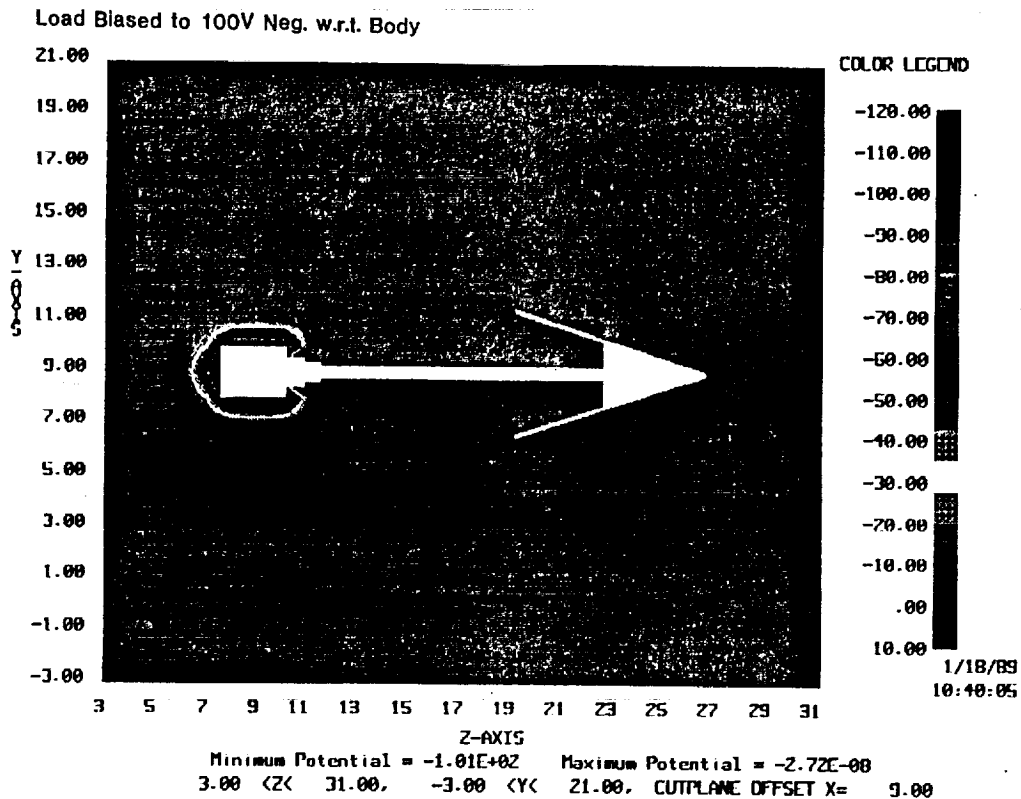
- S-CUBED DIV. OF MAXWELL LABORATORIES
- NASCAP (3-D, Particle Tracking)
  - Calculates Charging in GEO
  - Obtainable thru COSMIC
  - Mature Code, Industry Standard
- NASCAP/LEO (3-D, Particle Tracking)
  - Calculates Charging, Currents in LEO
  - Release thru COSMIC This Year
  - Under Final Testing
- EPSAT, EWB (1-D, Systems Tools)
  - Evaluate Multiple Interactions
  - Quick, Approximate
  - Under Beta Testing
  - May Be Ideal Starting Point for SEI



NASCAP model of NASA's  
Advanced Communications Technology Satellite.

Figure 6

SP-100 Floating Potential



## EPSAT's Architecture Combines A Powerful Display With Changeable & Expandable Modeling Capabilities

### Flexible Display Module

- same commands for all functions
- data entry screens
- tables
- line graphs
- contour plots

### Non-Procedural Process Controller

does only the calculations necessary  
for the desired result

### Workstation Independent

- UNIX
- Fortran & C
- Sun 3, 4 Sparc
- Compaq
- Celerity



### Object Oriented

message passing between modules

functional  
module

functional  
module

functional  
module

functional  
module

functional  
module

functional  
module

functional  
module

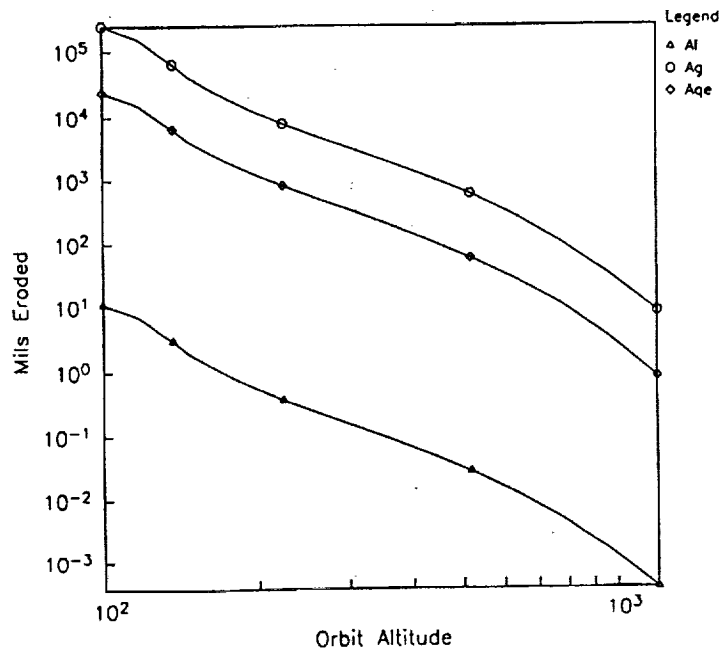
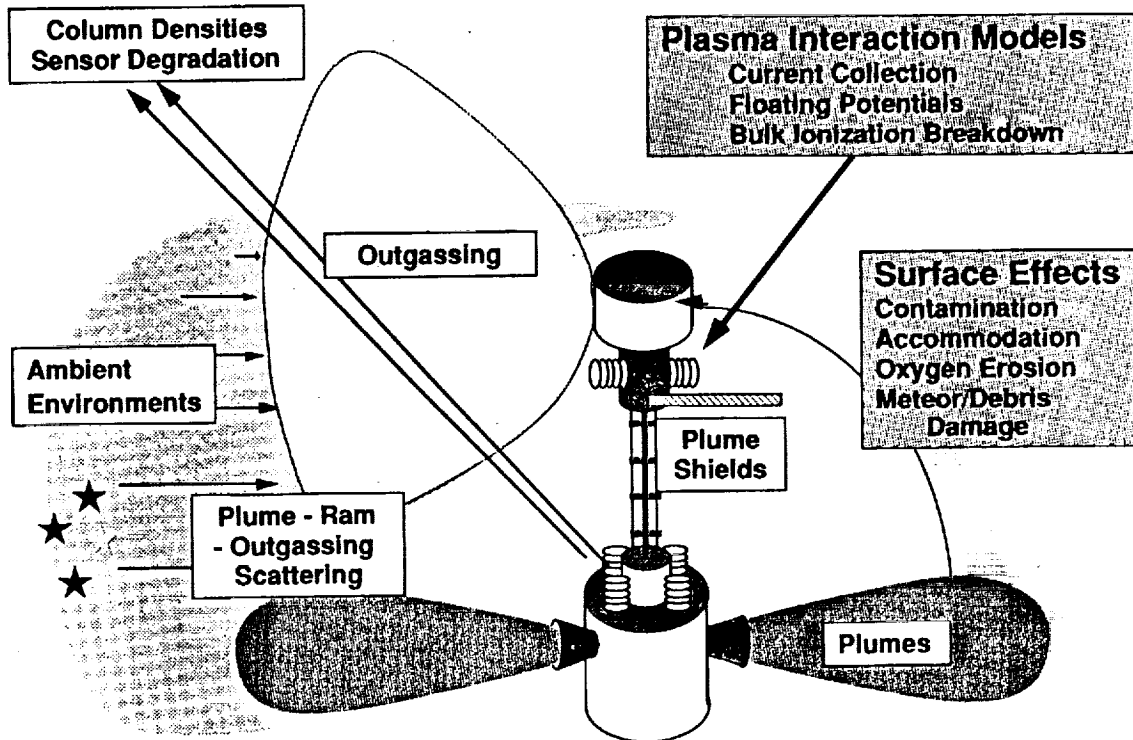
database

**Software  
"Expansion  
Slots"**  
plug in new or  
additional power  
system models

### Designed For Change

- editable screens
- text based data item dictionary
- coding standards
- all source government owned

# EPSAT Power System Models



Total atomic oxygen erosion during a 10-year mission life for three conductive coatings as a function of altitude for 60° inclination circular orbits.



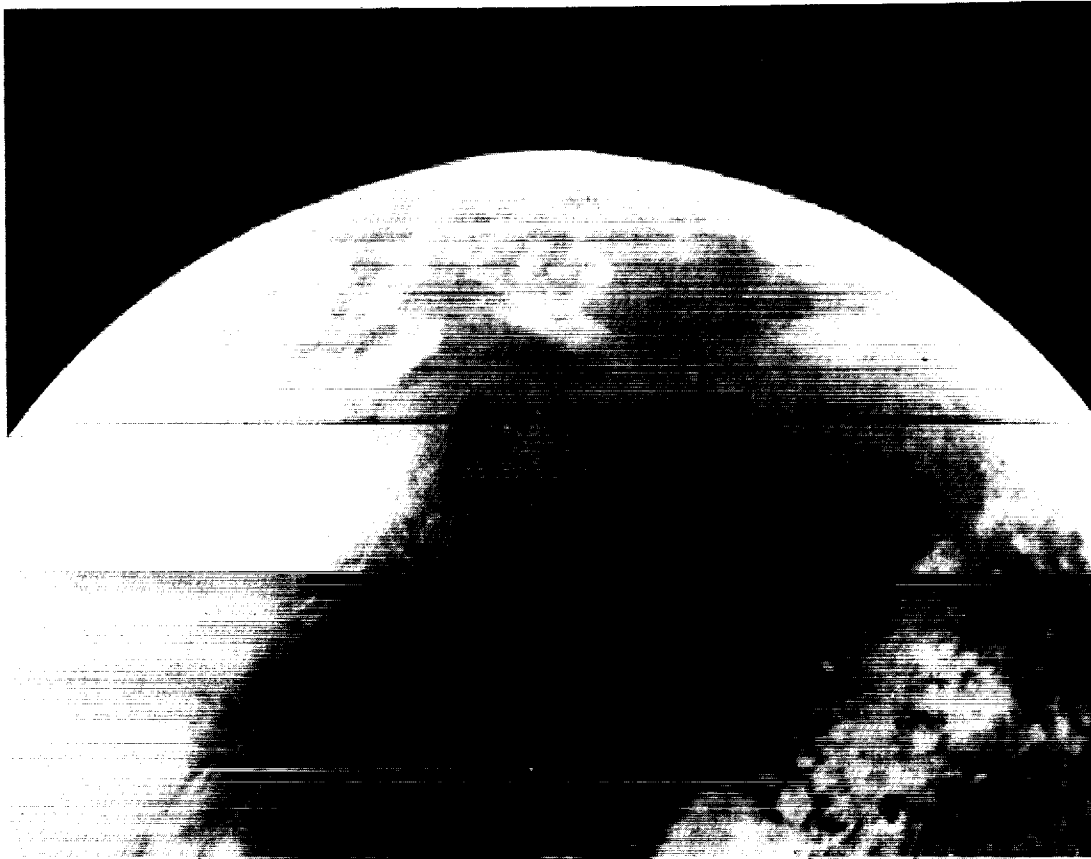
# KAPTON 41 HOURS EXPOSURE TO ATOMIC OXYGEN ON STS-8



## STS-8 FLIGHT SAMPLES

LARC PRELIMINARY MASS LOSS MEASUREMENTS  
(Corrected for mass change of control  
due to moisture, etc.)

SAMPLE #	DESCRIPTION	MASS CHANGE (g)	(Assumes $3.87 \times 10^{20}$ atoms/cm <sup>2</sup> )		COMMENT
			MASS CHANGE	ERROR	
1	5 mil Kapton, Al backed	-0.0050200 99	-3.88 x 10 <sup>-24</sup> 01		
2	5 mil Teflon, Al backed	-0.0000820 91	-6.34 x 10 <sup>-26</sup> 01		Low loss rate
3	5 mil Mylar, Al backed	-0.0056031 118	-4.34 x 10 <sup>-24</sup> 01		HIGHEST MEASURED
4	MgF <sub>2</sub> anti-reflection on glass	-0.0000204 259	-1.58 x 10 <sup>-26</sup> 2.01		No sig. change
5	ITO on glass	-0.0000190 359	-1.46 x 10 <sup>-26</sup> 2.78		No sig. change
6	96% SiO <sub>2</sub> + 4% PTFE on 5 mil Kapton	-0.0000103 52	-7.98 x 10 <sup>-27</sup> 4.04		Very low loss rate
7	Al <sub>2</sub> O <sub>3</sub> on 5 mil Kapton	-0.0005674 52	-4.40 x 10 <sup>-25</sup> 04		LOWEST MEASURED
8	SiO <sub>2</sub> on 5 mil Kapton	-0.0000053 52	-4.50 x 10 <sup>-27</sup> 4.04		No sig. change
9	TiO <sub>2</sub> on quartz	+0.0000437 147	+3.38 x 10 <sup>-26</sup> 1.14		Low gain rate
10	Mo on sapphire	+0.0000760 235	+5.88 x 10 <sup>-26</sup> 1.81		Low gain rate
11	Copper on sapphire	+0.0000764 767	+5.91 x 10 <sup>-26</sup> 5.93		No sig. change
12	Chromium on Kapton, Al backed	-0.0000492 147	-3.81 x 10 <sup>-26</sup> 1.14		Low loss rate

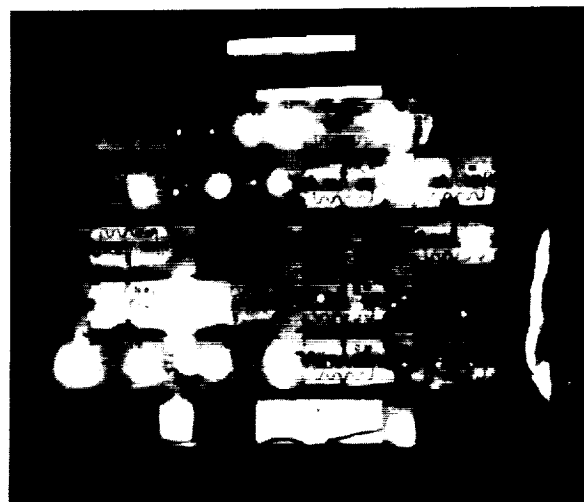
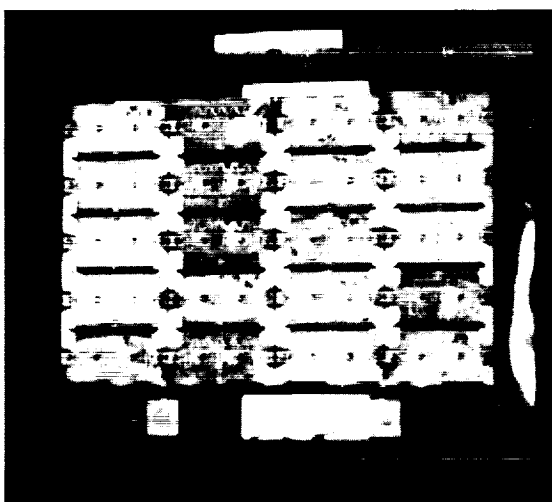
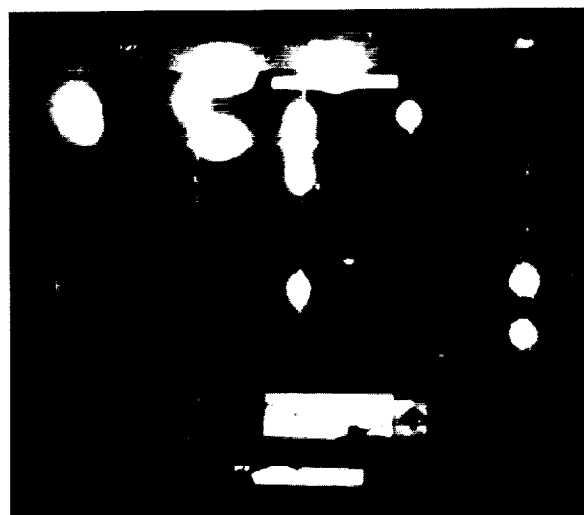
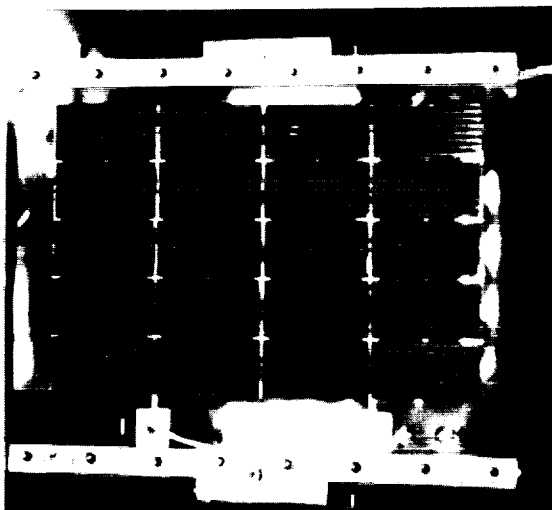


## Space Environmental Interactions

### Current Collection and Snapover

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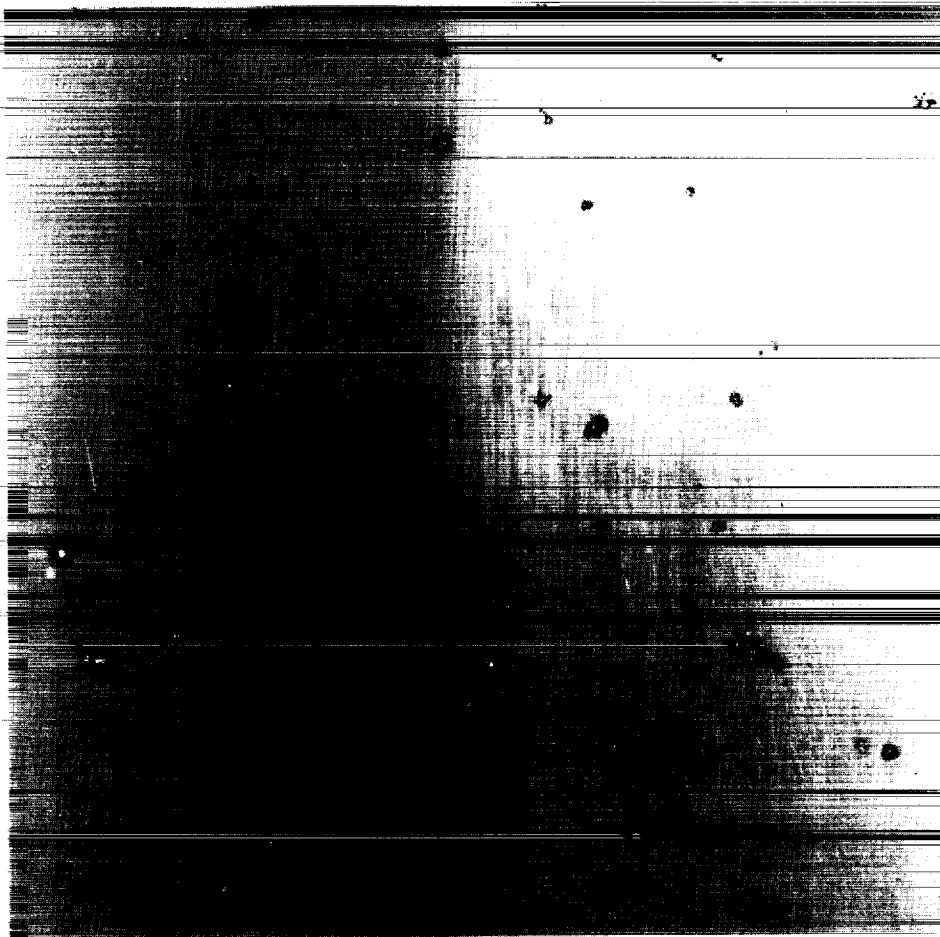
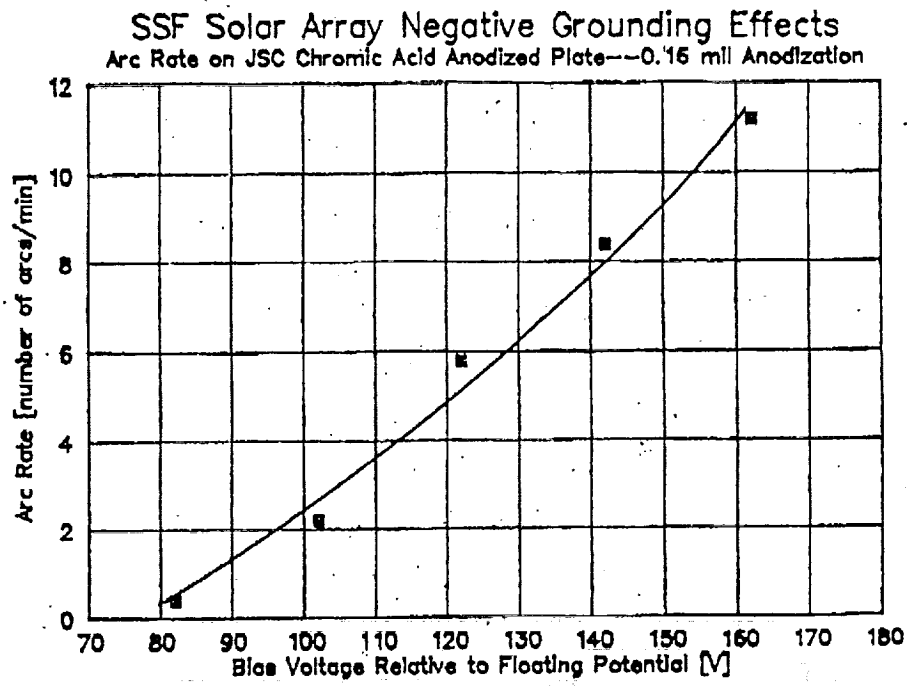
- ELECTRON COLLECTION AND SNAPOVER
  - Snapover at Potentials  $> +100$  V
  - Insulators Act as Electron Conductors
  - Large Power Drains
- ION COLLECTION AND SPUTTERING
  - Ions Focused Onto Insulation Defects
  - Sputtering at Potentials  $< -100$  V
- FLOATING POTENTIALS
  - Ion and Electron Currents Must Balance
  - Ease of Electron Collection Makes Systems Float Negative
- POWER SYSTEM GROUND IMPORTANT
  - Grounds on Moon, Mars Difficult?



ARCING ON SOLAR CELL ARRAY SAMPLES  
 2x4 cm WRAPAROUND CELLS ON KAPTON  
 -1 kV BIASED ARRAY CIRCUIT  
 $10^5 \text{ cm}^{-3}$  N PLASMA (25 eV IONS, 3 eV  $e^-$ )

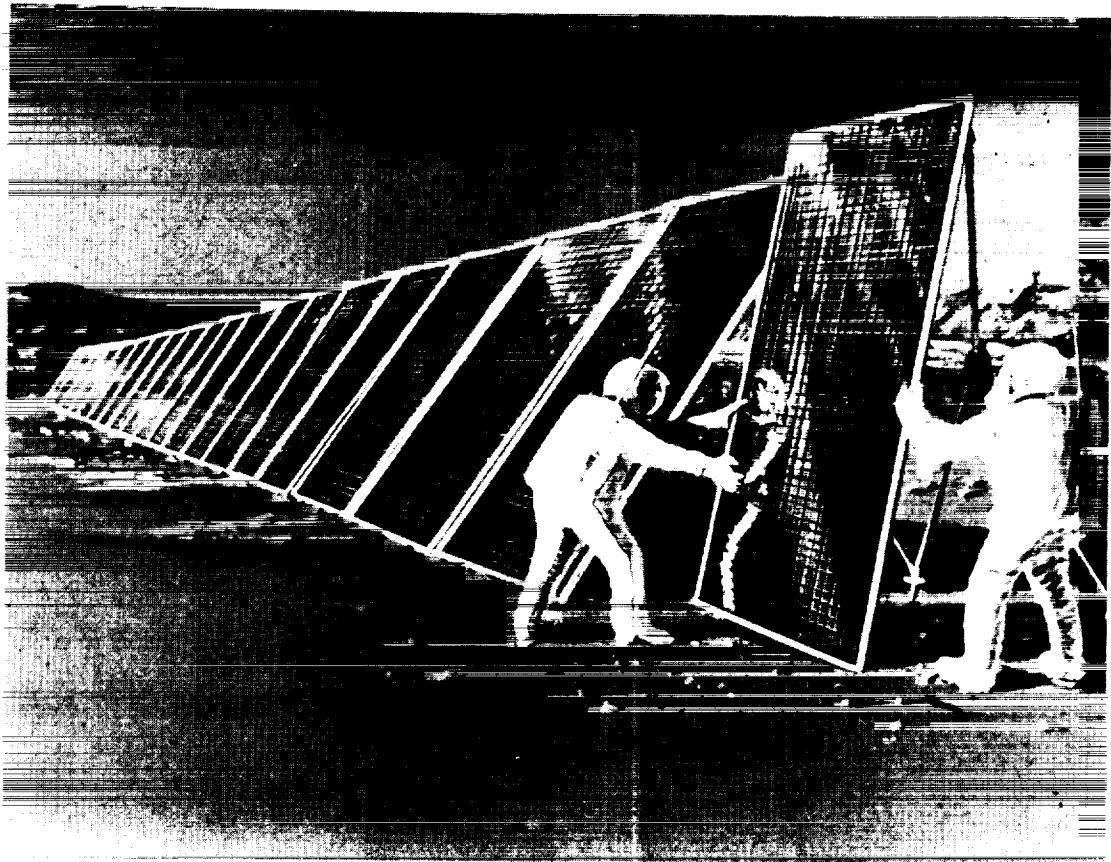
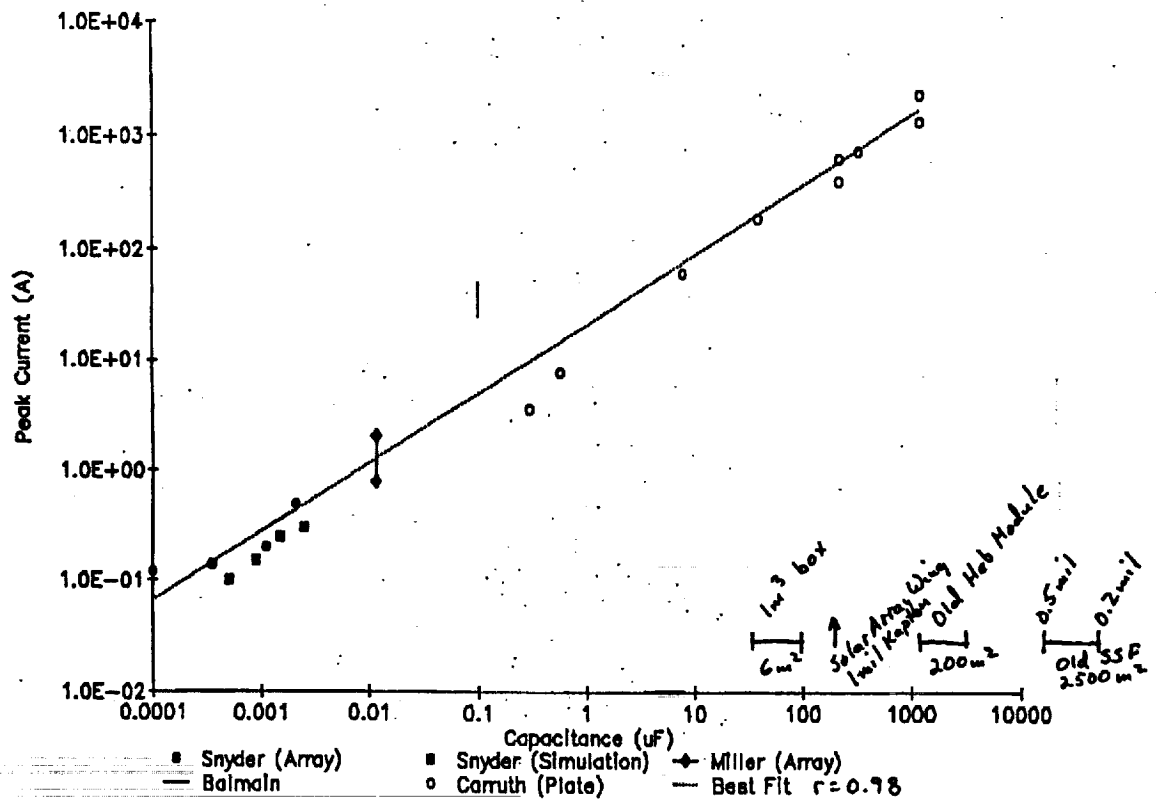
NASA/LEWIS RESEARCH CENTER  
 ENVIRONMENTAL INTERACTIONS PROGRAM

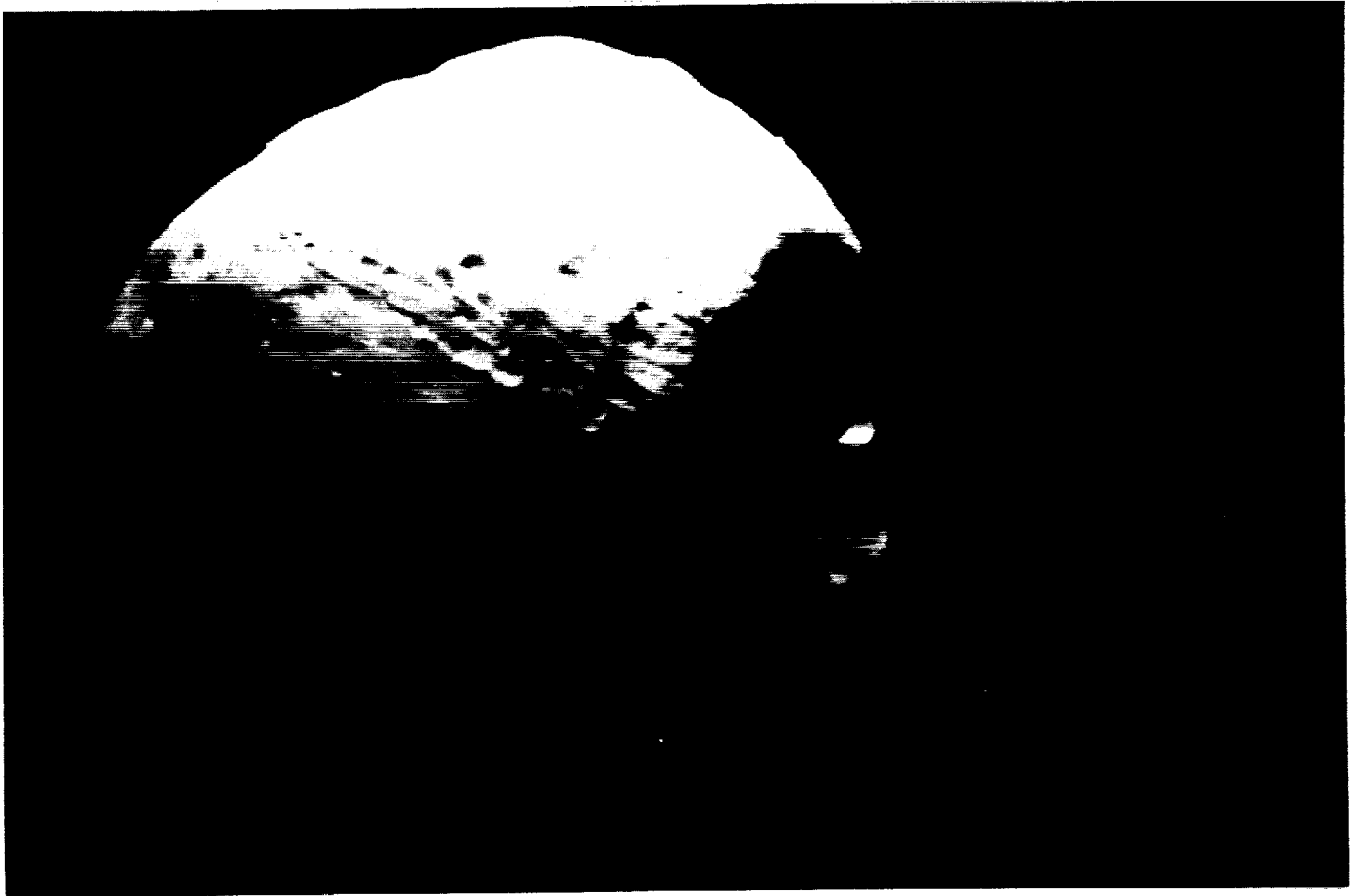
# DIELECTRIC BREAKDOWN OF ANODIZED SURFACES IN A PLASMA



# Peak Currents of Plasma Arcs

Best Fit Power:  $0.62 \pm 0.03$



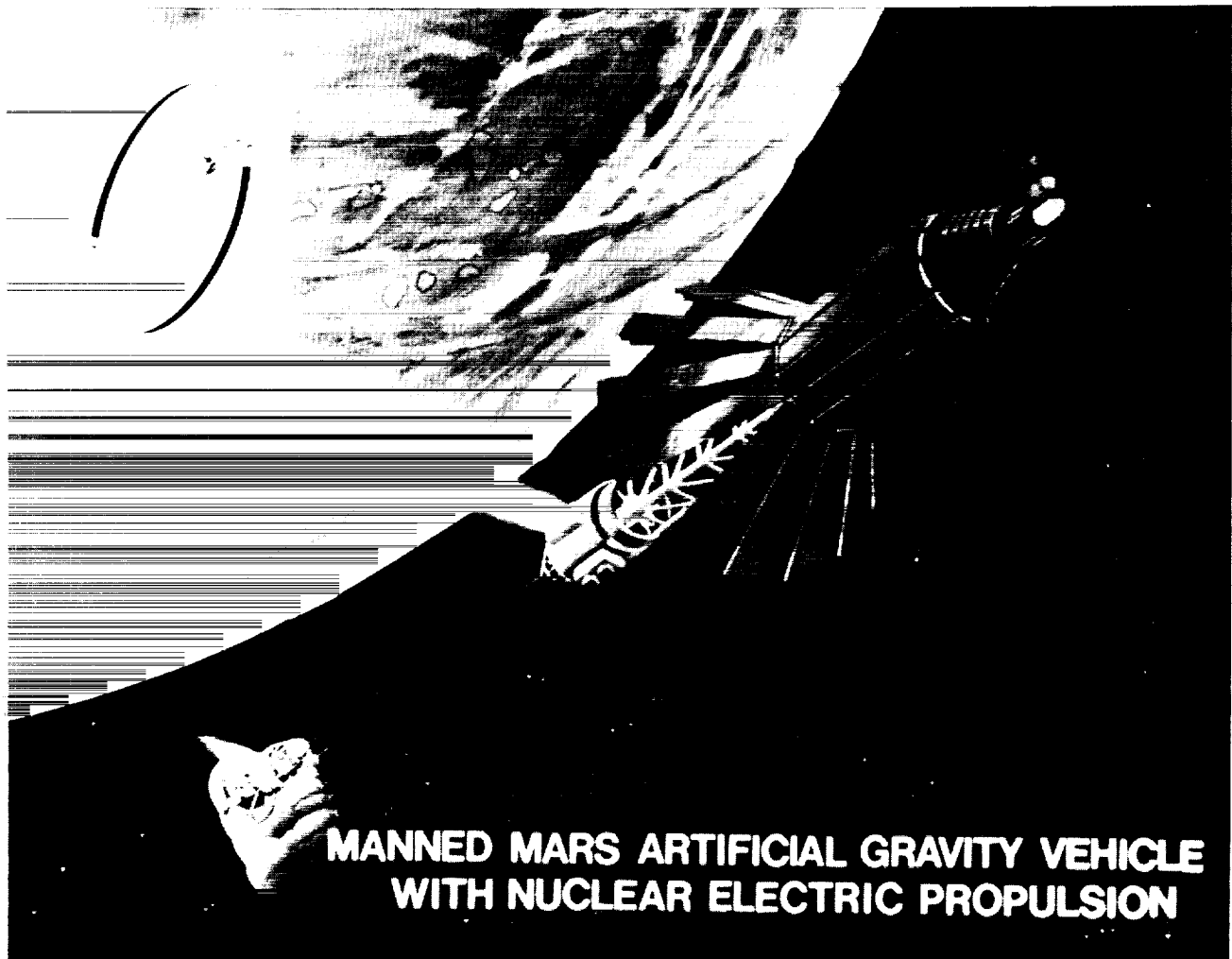


## Space Environmental Interactions

### Effluents, Neutral and Ionized

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- NEUTRAL EFFLUENTS
  - Thruster Firings and Gas Dumps
  - Change Vehicle Floating Potential
  - May Interact Chemically with Surfaces
  - May Become Ionized by UV, Critical Ionization Velocity, Charge Exchange
  - Source of Contamination
- IONIZED EFFLUENTS
  - Ion Thrusters, Radioactive Sources
  - May Be Attracted Back by E Fields
  - Change Vehicle Potential
  - Increase Local Plasma Density, Arcing, Sputtering, etc.

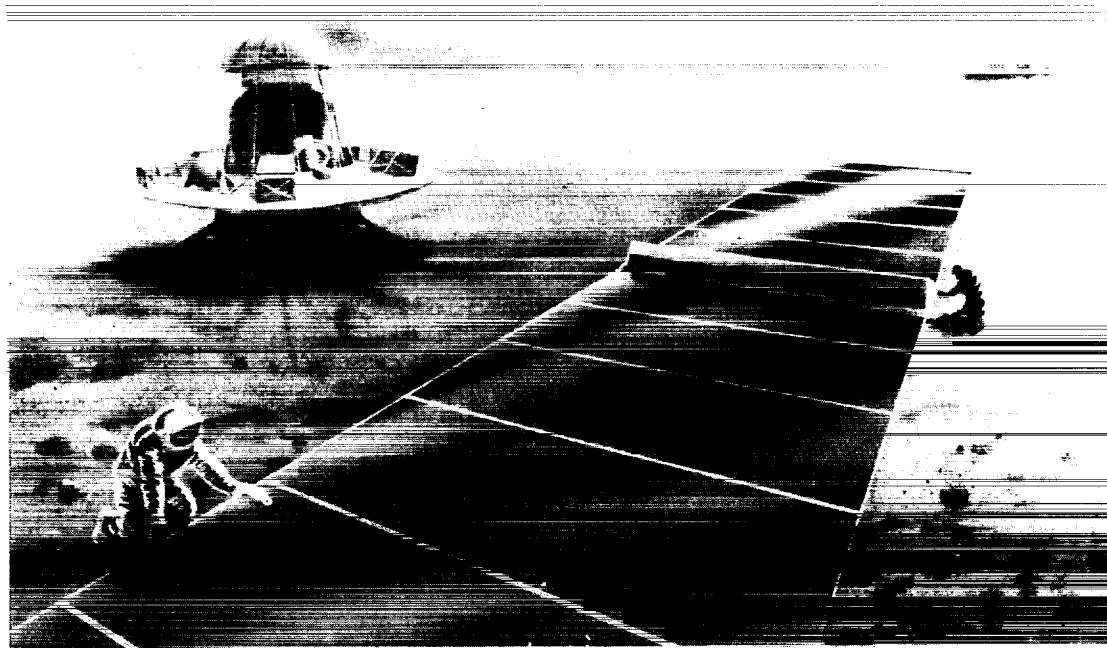
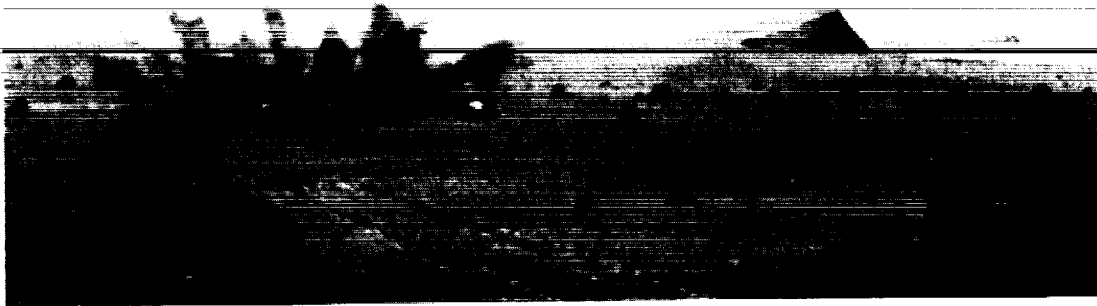


## Space Environmental Interactions

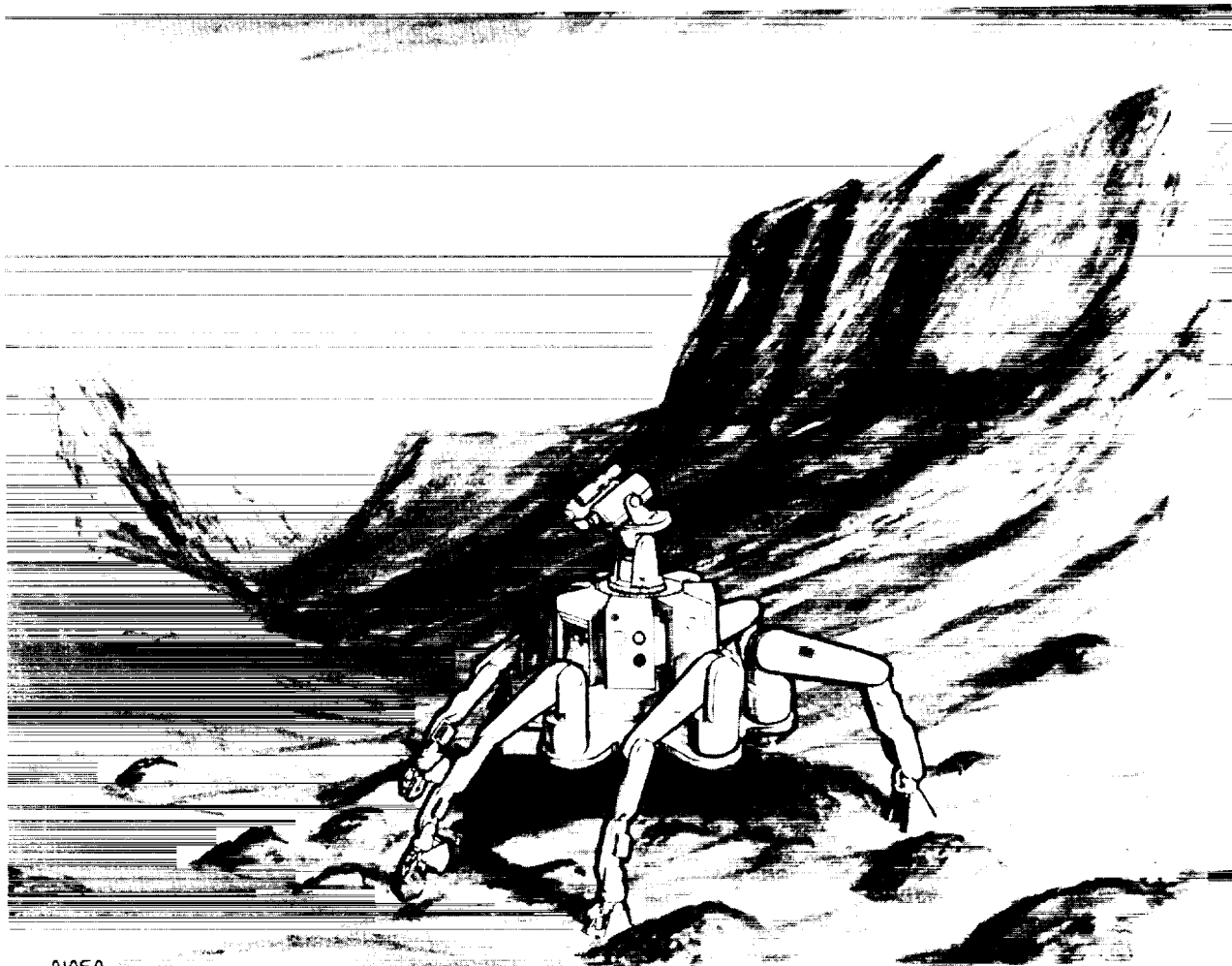
### Winds, Dust, and Contamination

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- **NEUTRAL DUST CONTAMINATION**
  - Propelled by Winds or Rocket Exhausts
  - May Have High Sticking Factors
  - Can Change Thermal, Optical Properties
  - Attracted to Charged Surfaces by Dipole Attractions
- **CHARGED DUST**
  - Mars, Moon - Photoelectric Effect
  - Mars - Triboelectric Charging
  - Attracted Strongly to Charged Surfaces







NASA

